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# *AVOIDANCE OF TIMEOUT FROM RESPONSE-INDEPENDENT FOOD: EFFECTS OF DELIVERY RATE AND QUALITY*

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In three experiments, a rat's lever presses could postpone timeouts from food pellets delivered on response-independent schedules. In Experiment 1, the pellets were delivered at variable-time (VT) rates ranging from VT 0.5 to VT 8 min. Experiment 2 replicated the VT 1 min and VT 8 min conditions of Experiment 1 with new subjects. Finally, subjects in Experiment 3 could postpone timeouts from delivery of pellets that differed in quality rather than quantity (unsweetened versus sweetened pellets). In general, response rates and success in avoiding increased as a function of the rate and quality of the pellets. Also, performance efficiency increased as the experiments progressed, that is, the avoidance response occurred later and later in the response-timeout interval. The results support the conclusion that timeout from reinforcement has functional properties similar to those of more commonly studied aversive stimuli (e.g., shock).

*Key words:* free-operant avoidance, timeout from food, variable time schedules, food amount, food quality, avoidance efficiency, lever press, rats

In the free-operant avoidance procedure developed by Sidman (1953), electric shocks are scheduled periodically, and each response postpones the impending shock by a fixed period of time. Examples of aversive events studied with this procedure include, in addition to electric shocks, such stimuli as bright lights, extreme temperatures, and loud sounds (Baron, 1991). However, periods of timeout from reinforcement also can serve as aversive stimuli. For example, Galbicka and Branch (1983) exposed pigeons to a procedure in which food was delivered on a response-independent basis. If the pigeon failed to peck the response key, a stimulus change occurred and the food schedule was suspended for 30 s. Thus, by occasionally responding the pigeon could repeatedly postpone the timeouts and maintain continual access to the food schedule. Food presentations within the avoidance paradigm also can be response dependent, in which case avoidance is accomplished by responding on a second key (e.g., Thomas, 1964).

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Research has shown that subjects will reliably respond to avoid periods of timeout. Moreover, such findings encompass a variety of species and reinforcing events. For example, on the human level, Baer (1960) found that preschool children would respond to avoid cessation of a cartoon movie that they were watching, and Baron and Kaufman (1966) studied avoidance responding by college students with timeout from monetary payment as the aversive event. However, most of the research with which we are concerned has employed nonhuman subjects (rats and pigeons) and timeout from food as the aversive event.

The present study was predicated on the assumption that if timeout from food delivery is aversive, then variables that control avoidance of timeout will have counterparts in the avoidance of shock. Several lines of evidence bear out this expectation. For example, Thomas (1965) manipulated timeout duration and found that increased durations were accompanied by increased rates of avoidance responding. These results parallel the heightened avoidance rates that accompany increases in shock intensity (Boren, Sidman, & Herrnstein, 1959).

Another important variable is the response–timeout interval, that is, the length of time that the response postpones the next scheduled timeout. D'Andrea (1971) manipulated the response–timeout interval across a range of values and found that increases in the interval were accompanied by decreased avoidance rates. In this regard as well, the outcome parallels the observation that increases in the response–shock interval are accompanied by decreases in avoidance rates (Sidman, 1953).

The presence or absence of a warning stimulus, that is, a stimulus preceding the aversive event, also play parallel roles in shock and timeout avoidance. van Haaren and Zarcone (1994) found that a procedure in which a warning stimulus was presented 10 s prior to the onset of timeout maintained behavior better than procedures that omitted the stimulus. This outcome mirrors the finding that a preshock stimulus facilitates responding to avoid shock (Ulrich, Holz, & Azrin, 1964).

Finally, the literature on shock avoidance suggests that the frequency of the event from which there is timeout should be a key variable in avoidance of timeout, in particular that timeouts from rich schedules of reinforcement are more aversive than timeouts from leaner ones. Here, the results have been less consistent. In one experiment, Thomas (1964) compared avoidance of timeout from two variable-interval (VI) schedules of food delivery: VI 1 min versus VI 9 min. Although he found differences between these two conditions, surprisingly, subjects manifested higher rates of avoidance responding when the leaner VI 9 min schedule was in effect. In addition, these findings were confirmed over a series of reversals of the two conditions. By comparison, D'Andrea (1971) studied avoidance of timeout from response-independent schedules using different variable-time (VT) schedules of food delivery: VT 30 s versus VT 60 s. As expected, timeout from the richer schedule (VT 30 s) produced higher avoidance rates. These opposite outcomes indicate the need for further investigations into the role of reinforcement frequency in avoidance of timeout.

Accordingly, the three experiments of this series constitute a further analysis of timeout avoidance when rates of food deliveries are varied. In addition, one of the experiments examined the role of food quality on the assumption that quantity and quality would have parallel effects (cf. Kimble, 1961). More specifically, the procedures exposed rats to response-independent schedules of food pellet delivery within a single lever chamber. Timeouts were programmed according to a free-operant avoidance schedule and avoidance of timeout was contingent on pressing the lever. In addition to the usual measures of avoidance (response rate, percentage of timeouts avoided), the temporal location of responses within the response–timeout intervals was analyzed. These latter data provided information about the efficiency of the avoidance response as a function of the various experimental manipulations.

## EXPERIMENT 1

The first experiment was designed to determine the extent to which performances varied across different rates of food delivery. Of particular interest was whether the findings would indicate a direct relationship (D'Andrea, 1971) or an inverse one (Thomas, 1964).

### Method

*Subjects*

Six male albino rats (Sprague-Dawley derived) were 7 months old at the start of the experiment. They had previously served in exploratory research used to develop the present procedures. Body weights were maintained at 80% of the weights of free-feeding control subjects, and feedings occurred at least 30 min after each session. Rats were housed in individual cages on a 16:8 hour light/dark cycle with free access to water. With a few exceptions, sessions were conducted daily during the middle of the light cycle.

*Apparatus*

A single-lever operant chamber, 30.5 cm by 25.4 cm by 31.8 cm, was enclosed within a sound-attenuating ventilated chest. Extraneous sounds were masked by white noise and the sound of a ventilating fan. The lever, which could be retracted, required a minimum force of about 40 g (0.40 N) to operate and was positioned 1.5 cm above the grid floor and 3 cm to the left of the food cup. Two small 2-W lamps, 1 cm apart, were positioned 1 cm above the lever. Pressing of the lever was accompanied by momentary illumination of the lamps and interruption of the background white noise. Food (45-mg Noyes pellets) was delivered to a cup positioned 0.5 cm above the grid floor. Illumination of the chamber was provided by a 3-W lamp mounted outside the

Table 1

Experiment 1. Mean percent pellets received and order of conditions.

| Schedule | Percent Received | Subjects R04 | R17 | R46 | R48 | R54 | R59 |
|---|---|---|---|---|---|---|---|
| VT 0.5 min | 93 (0.7) | 5 | 2 | 2 | - | - | - |
| VT 1 min | 92 (0.8), 92 (1.2) | 1,4 | 1,5 | 1,5 | 1,5 | 1,5 | 1,5 |
| VT 2 min | 94 (1.6) | 3 | - | - | 2 | 2 | 4 |
| VT 4 min | 90 (2.2) | 2 | 3 | 3 | 3 | 3 | 2 |
| VT 8 min | 84 (4.4) | - | 4 | 4 | 4 | 4 | 3 |
| No Pellets | - | 6 | 6 | 6 | 6 | 6 | 6 |

*Note.* Percent pellets received are based on mean values for subjects in each condition; standard errors are displayed in parentheses.

transparent plastic wall at the rear of the chamber. A microcomputer controlled experimental events and recorded the data.

### *Procedure*

During the main phases of the experiment, pellets were delivered according to one of several variable-time (VT) schedules, either VT 0.5 min, VT 1 min, VT 2 min, VT 4 min, or VT 8 min. During a final (no-pellet) condition, all scheduled pellet deliveries were canceled; however, the rat could still avoid the stimulus that had been correlated with the timeouts. The VT schedules were composed of 10 intervals and were constructed according to the constant probability distributions described by Fleshler and Hoffman (1962).

Timeouts were scheduled at 30-s intervals and lasted 30 s each. During the timeout, the lever was retracted, the chamber lights extinguished, and the pellets ordinarily delivered by the VT schedule were cancelled. Following a timeout, the lights were turned back on, the lever was reinserted, and the next timeout was scheduled to occur in 30 s (i.e., the timeout–timeout interval was 30 s). However, each response on the lever during the time-in period postponed the next timeout for 30 s (i.e., the response–timeout interval was 30 s). Thus, by responding on the lever at least once every 30 s, the rat could avoid all timeouts.

Preliminary procedures were designed to establish avoidance responding. After lever pressing for food pellets was shaped, subjects were exposed to a procedure in which pellets were delivered on a response-independent basis, and brief timeouts were presented at irregular intervals. Unlike the final avoidance schedule, the lever was not retracted during the timeout periods; however, a single response turned the lights back on and restored the food schedule. In addition to this escape contingency, responses on the lever during time-in periods postponed the timeouts by 30 s. Avoidance responses became increasingly frequent with this procedure, and, when the avoidance response was established, the procedure used subsequently was instituted: the escape contingency was removed by retracting the lever during the timeout periods, the VT schedule was increased to VT 1 min, and the duration of the timeouts was increased to 30 s.

A complication was that food pellet deliveries were scheduled independently of responding, thus making it possible for a response to be immediately followed by a pellet. This possibility was precluded by imposing a 3-s delay following each response so that responses were separated from pellets by at least 3 s. Of necessity, the delay contingency reduced the pellet delivery rates below the scheduled VT values. However, as shown in Table 1, most of the pellets scheduled for delivery during the time-in periods actually were delivered (fewer than 10% of the pellets were postponed because of the delay contingency).

Table 1 summarizes the order of conditions. Approximately 30 sessions were devoted to each condition except for the final no-pellet condition where observations were continued for a total of 60 sessions. The stability criterion used for all of the experiments required that the difference between the first and second 5-session blocks was no more than 10% of the 10-session mean. Except for the no-pellet condition, rates were stable when conditions were changed. All rats started with a VT 1-min schedule and then were advanced to leaner VT schedules. However, responding was not well maintained in 2 rats (R17 and R46) and they were exposed to the VT 0.5-min schedule before being advanced.

When the rat was placed in the test chamber at the start of a session the chamber was dark and silent except for the sound of the ventilating fan. The lever was extended, but inoperative. After a 30-s delay, the session began. Initiation of the schedule was accompanied by onset of the white noise and illumination of the chamber lights. When the session was over, the lever was retracted, the chamber was darkened and the white noise was turned off. Sessions ended after 40 min. Given the 30-s duration of the timeouts and the 30-s duration of the timeout–timeout interval, if the rat never responded, 40 timeouts would be experienced and half of the scheduled pellets would be lost.

### Results and Discussion

The six top panels of Figure 1 show rates of responding for each of the 6 subjects. These and subsequent analyses were based on the last 10 stable sessions at each VT value. In general, avoidance rates decreased as rates of pellet delivery were decreased from VT 1 min to the lowest rate (VT 4 min or VT 8 min). However, changes from a leaner to a richer schedule sometimes had anomalous effects on responding, most notably for R04 whose rates declined over the transition from VT 1 min to VT 0.5 min, and did not change from VT 4 min to VT 2 min. The return to the VT 1-min schedule (closed bars) led to higher rates for rats exposed to the VT 8-min schedule in the preceding condition (R17, R46, R48, and R54). However, in five of six cases rates did not recover to their initial levels at VT 1 min. The final no-pellet condition yielded the lowest response rate. It is noteworthy that subjects were still responding at appreciable rates after 60 sessions in this condition. Within-session performances also were examined. Systematic rate changes were not apparent, and warm-up effects, sometimes seen in studies of shock avoidance, were absent.

The percentage of total timeouts avoided is shown in the bottom panels of Figure 1. The results were similar to the response-rate measure: the percentages decreased with decreases in the pellet rates. When the VT 1-min schedule was reinstated, 2 of the subjects recovered to their previous levels; recovery was incomplete for the remaining 4.

The data were examined for evidence that responses were elicited by the delivery of food pellets rather than controlled by postponement of timeout. The top section of Table 2 shows the percentage of total responses in Experiment 1 that followed responses, pellets, or timeouts under two pellet rate conditions: VT 1 min and VT 8 min (VT 4 min for R04). Clearly, the large majority of responses followed responses, a finding consistent with the interpretation that responding was controlled by the avoidance contingency. An additional feature of the data was that responses following pellets were higher under the richer of the two schedules (VT 1 min) whereas responses following timeouts were lower. These findings reflected differences in the frequency of pellets and timeouts under the two conditions, in that the richer schedule involved not only higher pellet rates but also higher degrees of success in avoiding the timeouts (see Figure 1).

Although the subjects received extended training before the experiment proper began, we observed that as the experiment progressed, responses tended to occur later and later in the response–timeout intervals. Thus, the efficiency of responding increased with exposure to the avoidance schedule insofar as a given level of avoidance could be accomplished with fewer responses. To arrive at an index of efficiency, we determined the intervals separating responses, each of which initiated a new response–timeout interval, and values were assigned to one of ten 3-s bins according to the 30 s of the response–timeout interval. Early in training, most of the intervals were concentrated in the earlier values, but the values shifted toward longer values with continued exposure. To arrive at a summary measure, we concentrated on the positive tail of the distribution; across the different levels of training, the most appropriate measure corresponded to the top 25% of the distribution.

The top panel of Figure 2 displays efficiency scores in Experiment 1 as a function of increasing exposure to the avoidance schedule for each subject. Despite variation from subject to subject, efficiency levels generally increased during the course of the experiment. For some subjects, this change was quite substantial. For

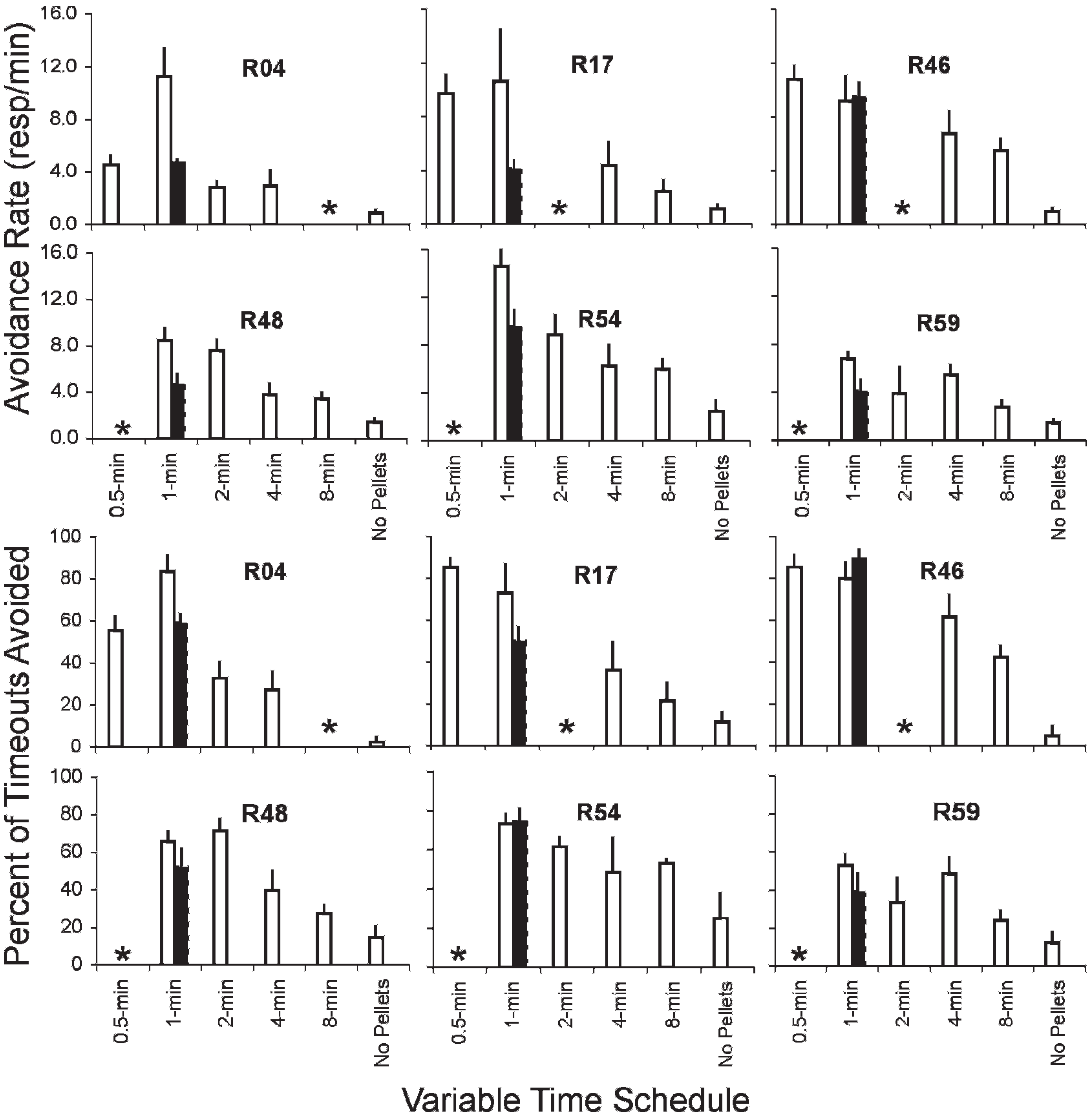


Fig. 1. Experiment 1. Rates of avoidance responding (upper panels) and percentages of timeouts avoided (lower panels) as a function of food delivery rate (VT 0.5 min, VT 1 min, VT 2 min, VT 4 min, VT 8 min). An asterisk marks those cases in which the rat was not exposed to a given condition. Closed bars depict the replication of the VT 1-min condition. Error lines designate standard errors.

example, the majority of responses by R17 occurred within the first 6 s of the response–timeout interval during the initial VT 1-min condition. When this condition was repeated (last point), the efficiency scores had increased to about 14 s.

The finding of a direct relationship between response and pellet rates is consistent with the assumption that the aversive properties of timeout depend on the value of the event from which there is timeout. However, because less frequent pellet rates tended to occur later in the experiment, an alternative interpretation is that the relationship reflected the reduced response rates that accompanied more efficient responding. Experiment 2 was designed to disentangle the variables of efficiency and pellet rate.

Table 2

Experiments 1–3. Percent responses following a response, a pellet, or a timeout.

| | | Subjects | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Experiment 1 | | R04 | R17 | R46 | R48 | R54 | R59 | Mdn |
| VT 1 min | Response | 88.1 | 88.8 | 87.8 | 83.2 | 89.3 | 81.3 | 88.0 |
| | Pellet | 9.5 | 9.4 | 10.6 | 12.6 | 8.6 | 12.8 | 10.1 |
| | Timeout | 1.5 | 1.8 | 1.7 | 4.2 | 2.0 | 5.9 | 1.9 |
| VT 8 min* | Response | 76.7 | 67.6 | 80.7 | 66.5 | 90.0 | 57.4 | 72.1 |
| | Pellet | 1.2 | 0.9 | 0.7 | 1.7 | 0.7 | 2.8 | 1.1 |
| | Timeout | 22.1 | 31.5 | 18.6 | 31.8 | 9.3 | 39.9 | 26.8 |

* R04 was observed under VT 4 min.

| Experiment 2 | | R08 | R10 | R14 | R15 | R16 | R18 | Mdn |
|---|---|---|---|---|---|---|---|---|
| VT 1 min | Response | 84.9 | 84.0 | 85.1 | 90.3 | 88.1 | 86.7 | 85.9 |
| | Pellet | 11.3 | 11.9 | 11.8 | 8.1 | 9.7 | 10.2 | 10.8 |
| | Timeout | 3.8 | 4.1 | 3.1 | 1.6 | 2.2 | 3.1 | 3.1 |
| VT 8 min | Response | 71.2 | 56.8 | 74.7 | 77.4 | 53.3 | 53.2 | 64.0 |
| | Pellet | 3.3 | 6.8 | 2.7 | 2.4 | 4.1 | 4.0 | 3.7 |
| | Timeout | 25.5 | 36.4 | 22.6 | 20.2 | 42.6 | 42.8 | 31.0 |
| Experiment 3 | | R82 | R83 | R84 | R86 | Mdn | | |
| Unsweetened | Response | 84.1 | 80.5 | 89.1 | 89.7 | 86.6 | | |
| | Pellet | 10.6 | 14.0 | 8.9 | 8.3 | 9.8 | | |
| | Timeout | 5.3 | 5.5 | 2.0 | 1.9 | 3.6 | | |
| Sweetened | Response | 88.1 | 88.0 | 82.0 | 84.1 | 86.0 | | |
| | Pellet | 9.3 | 10.0 | 13.0 | 12.4 | 11.2 | | |
| | Timeout | 2.6 | 2.0 | 5.0 | 3.5 | 3.1 | | |

## EXPERIMENT 2

The procedures of Experiment 1 were simplified by limiting comparisons to two disparate schedules of pellet delivery: VT 1 min versus VT 8 min. These conditions were then replicated, thus providing information about frequency effects when subjects had a greater degree of experience with the schedule.

### Method

#### *Subjects and Apparatus*

Six male hooded rats (Long-Evans derived) were 8 months old at the start of the experiment. These animals had previously served in a student laboratory where they were trained to respond on FR and VI schedules. Other details, including the apparatus, were similar to those described for Experiment 1.

#### *Procedure*

Avoidance parameters (i.e., response–timeout intervals, timeout–timeout intervals, and timeout durations) were unchanged from Experiment 1. However, during preliminary training, when the rat could either escape or avoid, the escape requirement was increased from a single response (FR 1) to FR 3 and then to FR 5. This modification, by increasing the frequency of responding, had the effect of facilitating the transition from escape to avoidance. The final procedure was as in Experiment 1; a single response during the time-in period postponed the next timeout for 30 s.

The main phase of the experiment involved observations with the VT 1 min schedule and then the VT 8-min schedule. These two conditions were then repeated. To reduce the extent of differences in schedule experience between the original and repeated conditions, each condition was imposed for 15 sessions, by comparison with the 30 or more sessions of Experiment 1. If stability was met by the 15th session, the subject was advanced to the next condition. Otherwise, an additional five sessions were added. Table 3 summarizes the number of sessions in each condition. The table also shows that at least 80% of the pellets scheduled by the VT schedule were actually delivered.

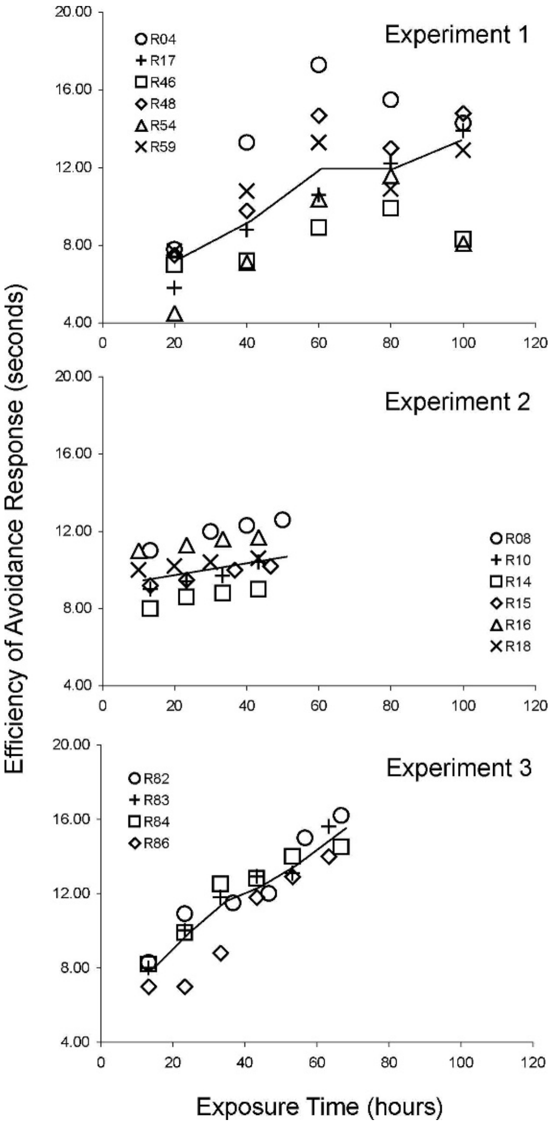


Fig. 2. Experiments 1–3. Response efficiency as a function of hours of exposure to the avoidance schedules. Efficiency is indexed as the point within the 30-s response–timeout interval that corresponded to the top 25% of the distribution. Note that the points for individual subjects are sometimes displaced depending on differences in the extent of exposure to a given condition. Median values for the aggregated subjects also are shown.

### Results and Discussion

The analyses followed the same format as for Experiment 1. The six top panels of Figure 3 show that avoidance rates were systematically higher for VT 1 min than for VT 8 min, thus confirming one of the essential findings of Experiment 1. Moreover, replication of the two conditions within Experiment 2 yielded generally equivalent performances for the initial and subsequent comparisons. The bottom panels show similar outcomes for percentage of timeouts avoided, in that subjects avoided more timeouts under the VT 1-min condition than the VT 8-min condition.

Results summarized in the middle section of Table 2 provide information about the events preceding responses in Experiment 2. As in Experiment 1, the majority of responses followed responses. Also, as previously observed, by comparison with the VT 1-min condition, responses under the leaner, VT 8-min condition were less likely to follow pellets and more likely to following timeouts.

Concerning the efficiency of performances, the middle panel of Figure 2 shows that initial values were higher, on the average, than in Experiment 1; however by the end of Experiment 2 differences were reduced considerably. Overall, increases in efficiency values were smaller than was observed in Experiment 1. Two possible reasons for this difference are differences in the preliminary training procedure and differences in the degree of exposure to the avoidance schedule. In the latter regard, Experiment 2 encompassed, at most, a total of 50 hrs by comparison with 100 hrs in Experiment 1.

When considered as a whole, the results of Experiment 2 revealed a strong relationship between response rates and pellet delivery rates in the absence of major differences in response efficiency. Thus, the results argue against the interpretation that differences in Experiment 1 under the different VT conditions were a consequence of differences in efficiency.

## EXPERIMENT 3

Experiment 3 was designed to extend the findings of the previous experiments by determining whether variations in the pellet quality would yield outcomes similar to those for pellet rates. Quality was varied by contrasting performances maintained with unsweetened pellets (as was the case in Experiments 1 and 2) with sweetened pellets. The procedure also was designed to strengthen the conclusion that responding was maintained by postponement of the timeouts rather than the immedi-

Table 3

Experiment 2. Mean percent pellets received and number of sessions under each condition.

| Condition | Percent Received | Subjects | | | | | |
|---|---|---|---|---|---|---|---|
| | | R08 | R10 | R14 | R15 | R16 | R18 |
| VT 1-min | 93 (0.9) | 20 | 20 | 20 | 20 | 15 | 15 |
| VT 8-min | 86 (3.4) | 25 | 15 | 15 | 15 | 20 | 15 |
| VT 1-min (replication) | 92 (1.0) | 15 | 15 | 15 | 20 | 15 | 15 |
| VT 8-min (replication) | 84 (3.6) | 15 | 15 | 15 | 15 | 15 | 20 |

*Note.* Percent pellets received are based on mean values for subjects in each condition; standard errors are displayed in parentheses.

ate delivery of a pellet. Under some of the conditions of Experiment 3 the resetting delay imposed between a response and pellet delivery was increased from 3 s (as in Experiments 1 and 2) to 6 s. If responding was controlled by the proximity of pellet deliveries, then increasing the delay should decrease responding.

## Method

### *Subjects and Apparatus*

Four male albino rats (Sprague-Dawley derived) were 7 months old at the start. As in Experiment 2, animals had served in a student laboratory where they were trained with FR and VI schedules. Other details were similar to those for Experiments 1 and 2.

### *Procedure*

As before, 45 mg food pellets (Noyes) were delivered in the experimental chamber. However, two types of food pellets were employed, either unsweetened or sweetened. Previous research using the same type of pellets (Bizo, Kettle, & Killeen, 2001) reported higher lever pressing rates for the sweetened pellets. Our own informal observations confirmed that given a choice, the rats preferred the sweetened ones.

Procedures were similar to those followed in Experiment 2 with the exception that pellets always were delivered according to the VT 1-min schedule. When the avoidance response was established (the pellets were unsweetened during preliminary training), subjects were advanced to the first of six conditions. As shown in Table 4, sweetened pellets were delivered during three of the conditions and unsweetened pellets in the other three. During Conditions 1–4, the minimum delay between responses and pellet delivery was set at 3 s, the value previously used. In Conditions 5–6 the duration was increased from 3 to 6 s. Training was continued under each condition until the previously described stability criterion was met. This usually was accomplished within fifteen 40-min sessions, although an additional five sessions were sometimes needed. The order of conditions for individual animals and the percent pellets received are summarized in Table 4.

## Results and Discussion

The four top panels of Figure 4 show higher rates of avoidance responding for the sweetened pellets than for the unsweetened ones. This was the case during the initial comparison (open bars), the replication (closed bars), and the final comparison when the minimum delay was increased from 3 s to 6 s (striped bars). Noteworthy is that rate differences were observed following different durations of exposure to the avoidance schedule and that increases in the minimum delay from 3 s to 6 s had little or no effect on response rates. This latter finding substantiates the interpretation that responding was maintained by avoidance of periods of timeout from pellet delivery rather than the adventitious delivery of a food pellet. As was the case in Experiments 1 and 2, the delay contingency was infrequently encountered (less than 10% of total responses). The bottom panels of Figure 4 show parallel outcomes for percentage timeouts avoided. More timeouts were avoided when pellets were sweetened and variations in the delay duration had inconsequential effects.

On the question of the events that preceded responses, the bottom section of Table 2 shows that most responses followed responses, and that differences between pellet conditions are absent. Generally, the percentages are consistent with those observed in Experiments

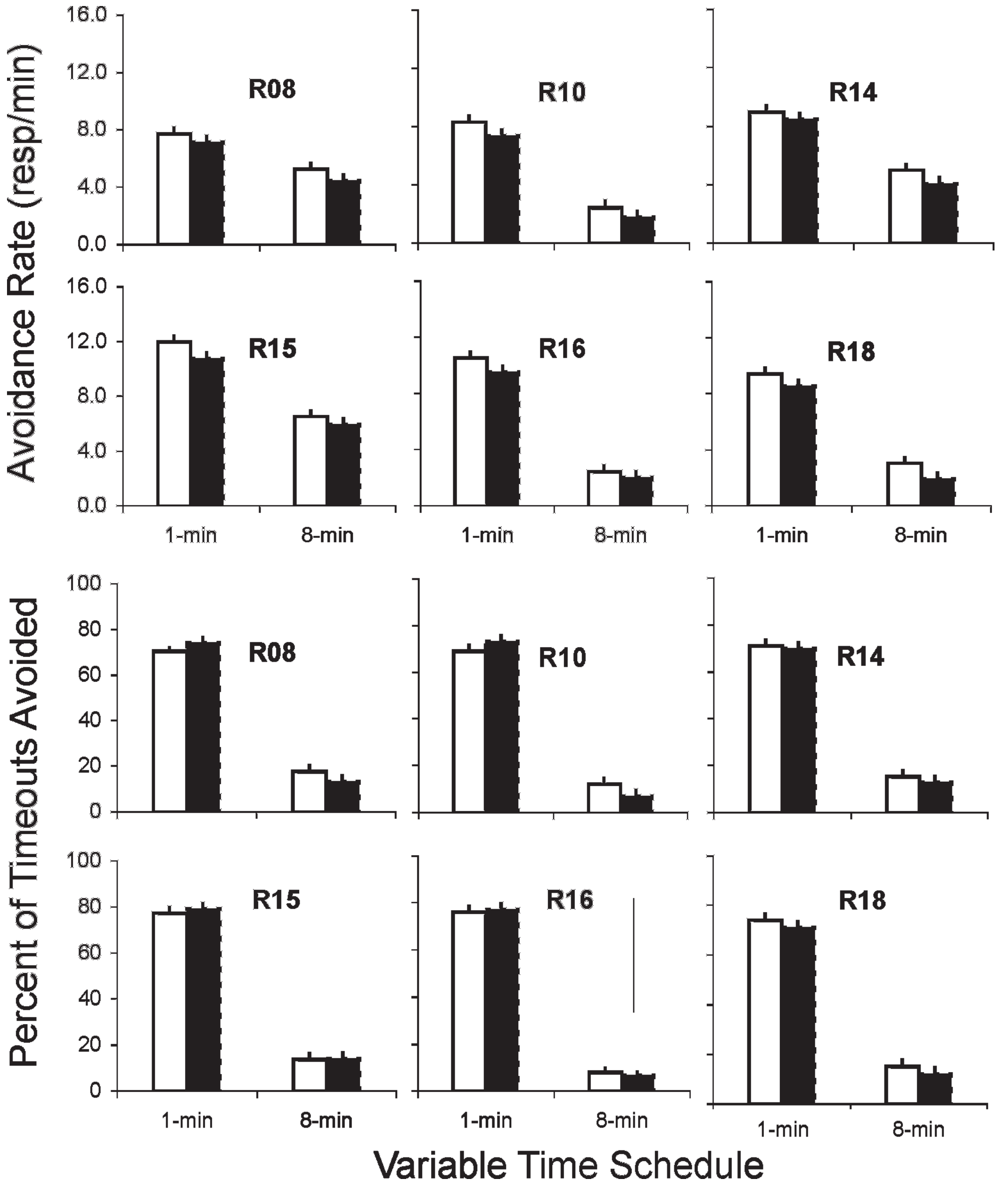


Fig. 3. Experiment 2. Rates of avoidance responding (upper panels) and percentages of timeouts avoided (lower panels) as a function of food delivery rate (VT 1 min versus VT 8 min). Closed bars depict replications of the two conditions. Error lines designate standard errors.

1 and 2 when pellets were delivered at the VT 1-min rate.

With regard to efficiency of avoidance responding, data in the third panel of Figure 2 show that values increased as Experiment 3 progressed. For reasons that we cannot specify, the extent of the increases exceeded those of the previous two experiments. Clearly, the differences cannot be attributed either to degree of exposure (exposure was greater in Experiment 1) or to the preliminary training procedures (similar procedures were used in Experiment 2).

## GENERAL DISCUSSION

The major finding of the three experiments was that timeout from food delivery main-

Table 4

Experiment 3. Mean percent pellets received and order of conditions.

| | | Subjects | | | |
|---|---|---|---|---|---|
| Condition | Percent Received | R82 | R83 | R84 | R86 |
| Unsweetened (3-s delay) | 89 (0.9), 87 (1.1) | 1,3 | 1,3 | 2,4 | 2,4 |
| Sweetened (3-s delay) | 92 (1.1), 93 (0.7) | 2,4 | 2,4 | 1,3 | 1,3 |
| Unsweetened (6-s delay) | 86 (1.1) | 5 | 5 | 6 | 6 |
| Sweetened (6-s delay) | 87 (0.9) | 6 | 6 | 5 | 5 |

*Note.* Percent pellets received are based on mean values for subjects in each condition; standard errors are displayed in parentheses.

tained responding within the free-operant avoidance paradigm. Experiments 1 and 2 showed that both response rates and percent timeouts avoided depended on the rate of food delivery that was suspended. Outcomes were similar in Experiment 3 when the quality rather than the quantity of the pellets varied.

These results are consistent with the literature on reinforcer preference which has identified rate and quality as important attributes of the reinforcement process (Baum & Rachlin, 1969; Fisher & Mazur, 1997). The earlier study by D'Andrea (1971) also showed that avoidance responding increased as a function of pellet delivery rate. However, the present procedures were more comprehensive in that rates were varied across a wider range of values. The further finding that avoidance also varied as a function of pellet quality has not been reported previously. However, the parallel influences of pellet quality and pellet rate have counterparts in the shock avoidance literature. For example, Sidman (1953) varied shock–shock rates from 2/min to 24/min and found that response rates increased as a function of shock rate. Boren, Sidman, and Herrnstein (1959) obtained similar findings when the intensity (quality) of the shock was increased from a low level (0.2 mA) to a high level (3.0 mA). Taken together, these findings provide additional evidence for the functional similarity of timeout and other more commonly studied aversive events.

A complication was that the design of Experiment 1 involved progressive reductions in pellet delivery rates across the sequence of conditions. The observation that response efficiency increased across the same sequence (that is, the tendency for responses to occur later in the response–timeout interval) opened the door to the interpretation that exposure to the avoidance schedule rather than pellet rate was a factor, if not the key factor, controlling differences. However, the results of Experiment 2 argued against such an interpretation by showing changes in avoidance rates in the absence of equivalent changes in response efficiency.

The progressive changes in efficiency that were observed in all three experiments were unanticipated, and we could not find studies of either shock or timeout avoidance that have subjected this phenomenon to systematic study. Moreover, as we noted in discussing specific results, although increases occurred in all three experiments, the rate of increase was not consistent. However, the increases do bear similarities to those reported for other temporally-based schedules, for example, the finding that extended training with fixed interval schedules increases tendencies to respond later in the interval (e.g., Baron & Leinenweber, 1994). Because data from avoidance experiments are not usually analyzed in terms of efficiency, the extent of interactions with more commonly studied variables is unknown. The present results suggest the need to consider this possibility.

We also considered the possibility that responses were elicited by pellet deliveries rather than by the postponement contingency. Clearly, if this was the case the contention that performances represented avoidance behavior would be seriously compromised. In fact, the results convincingly demonstrated that most responses followed responses rather than pellets, thus supporting the contention that avoidance rather than pellet-elicited behavior was being observed. A similar issue arises in the case of shock avoidance, insofar as putative avoidance responses may actually be elicited by the shocks. For example, an animal that

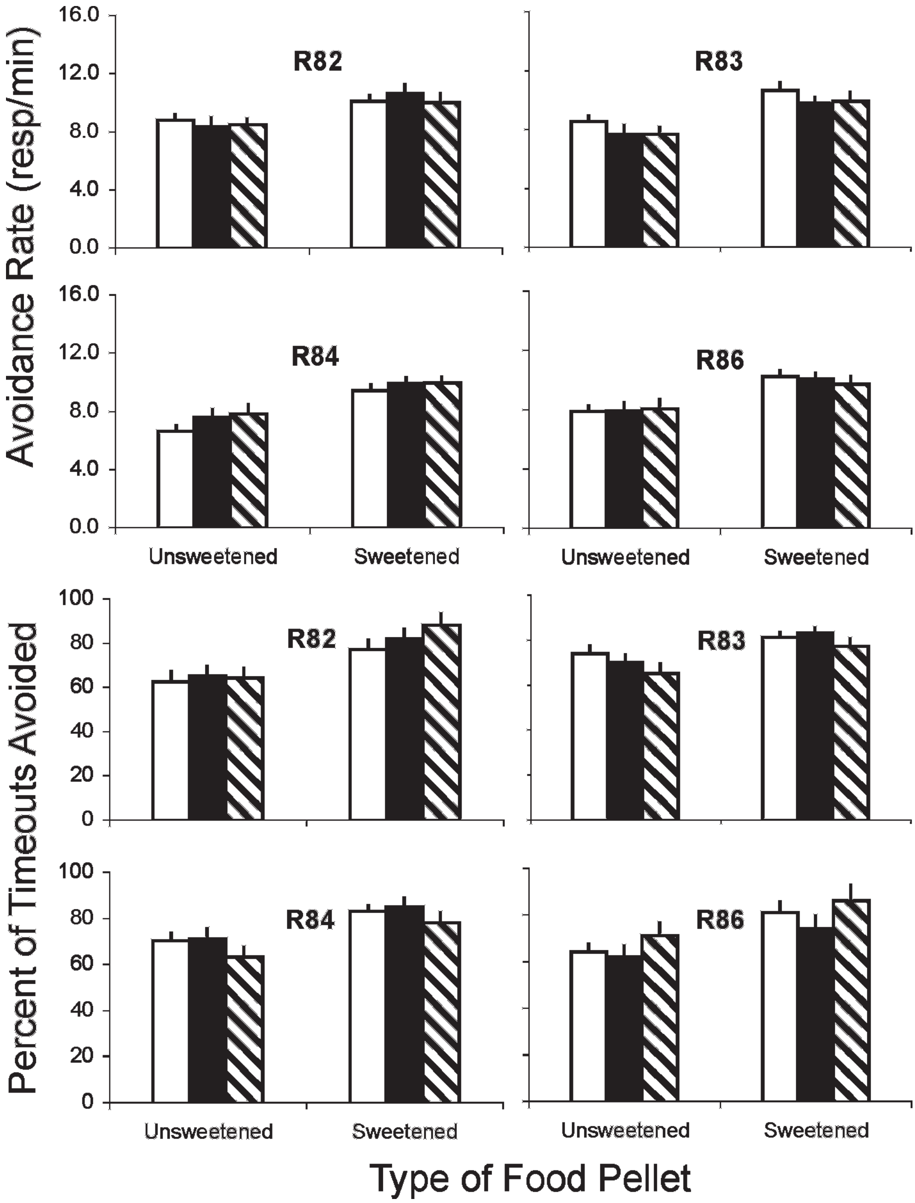


Fig. 4. Experiment 3. Rates of avoidance responding (upper panels) and percentages of timeouts avoided (lower panels) as a function of pellet quality (sweetened versus unsweetened). The closed bars depict replications of the original conditions. During the third condition (striped bars), the minimum delay separating a lever press from a pellet delivery was increased from 3 s to 6 s. Error lines designate standard errors.

''freezes'' on the lever and then releases and presses it in response to a shock can substantially reduce the shock rate (Baron, 1991).

The findings of both Experiments 1 and 2 as well as those of D'Andrea (1971) are contrary to those from the carefully done study reported by Thomas (1964) in which richer schedules were less effective in maintaining avoidance than leaner ones. The exact basis for Thomas's contrary results is difficult to specify. However, two procedural differences may be important. First, Thomas's experiments used pigeons as subjects in contrast to rats in the present and in D'Andrea's experiments. However, an account in these terms runs contrary to the literature which has demonstrated interspecies generality of timeout effects. Second, in Thomas's study pellets were delivered on a response-dependent rather than a response-independent schedule. A possibility is that a richer response-dependent schedule may have attracted behavior away from the avoidance key, thus leading to reduced rather than increased avoidance rates. We do not know of experiments that directly compared response-dependent and response-independent food delivery procedures; however, studies in the literature that have used one or the other of the two procedures do not suggest that the dependency is a critical factor (e.g., Galbicka & Branch, 1983; Thomas, 1964).

Throughout this report, we have proceeded on the assumption that responding was maintained by negative reinforcement (by avoidance of the timeout periods). However, it is important to acknowledge that the present findings do not disallow the alternative interpretation that responding was controlled by positive reinforcement (by the prolongation of time-in periods that accompanied responding). It appears impossible to eliminate this confound between positive and negative reinforcement without altering the contingencies of the free-operant schedule used in the majority of timeout studies. Moreover, similar questions can be raised with respect to shock avoidance. Responding may be maintained because it produces periods of safety (positive reinforcement) or because it reduces periods of danger (negative reinforcement) (Baron, 1991).

In the case of timeout, some writers have argued on the grounds of parsimony that interpretations in terms of positive reinforcement should take precedence except when it can be established that responding does not increase the rate of positive reinforcement (e.g., Leitenberg, 1965). Using this criterion, Pietras and Hackenberg (2000) provided evidence for the priority of negative reinforcement, but only by deviating from the free-operant procedure (they employed a discrete-trial procedure).

By comparison with emphases on the priority of positive reinforcement, research on free-operant avoidance of timeout has taken for granted from the start that substituting timeouts for shocks within Sidman's free-operant avoidance procedure retains the aversive properties of the schedule (see, for example, the title of the earliest experimental report; Morse & Herrnstein, 1956). The present study was conducted within this long-standing tradition. Clearly, the results cannot resolve the intractable question of the source of reinforcement control when organisms avoid either timeout or shock. In our view, the most prudent interpretation follows Michael's (1975) proposal that specification of reinforcing events must acknowledge both the presentation and removal of stimuli (for a more recent discussion of this issue see Baron & Galizio, 2005, as well as the commentaries in subsequent issues of the same journal).

In summary, the results of the present study showed that avoidance of timeout depends on the rate and quality of food presented during nontimeout periods. If the schedule of food is infrequent or the food is of lower quality, the timeout is not as aversive as when the schedule includes more frequent food deliveries or higher quality food. The use of timeout in applied situations such as classrooms, residential facilities, and as a parental disciplinary technique points to the need for further research on its parameters. The present research suggests that the effectiveness of timeout is directly affected by the environment in which this behavior control technique is employed. More specifically, timeout can be expected to be most effective when used to alter behavior within environments that are rich in reinforcers.

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